Environmental Science and Policy 93 (2019) 1–10

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Including quality in Social network analysis to foster dialogue in urban resilience and adaptation policies

Marie-Christine Therrien*, Mathilde Jutras, Susan Usher

École nationale d'administration publique, Canada

ARTICLE INFO

Keywords:
social network analysis
urban resilience
adaptation
policy implementation

ABSTRACT

The capacities of organizational actors increase when they are linked in network relationships, especially when confronting complex problems such as climate change adaptation and the development of resilience. This Social Network Analysis (SNA) of organizations working on adaptation to climate change and resilience on the territory of Montreal was conducted to provide insights into the implementation of policies in these areas. The analysis reveals a fairly uniform network with organizational links gravitating around two poles: one focused on local action and the other on policy design. The density of relationships is weak overall, and there is medium centralization around the City of Montreal. While centralization is beneficial for coordination, a structure involving more distinct sub-networks linked to central actors by boundary (broker) organizations would improve prospects for innovation and efficiency. Analysis of the quality of relationships highlights important differences between what fosters good relations in each of the poles, reducing the chances that policies developed in the policy-oriented pole will be implemented in the action-oriented pole. Overall, this study emphasizes the relevance of network analysis in understanding prospects for policy implementation in complex areas such as resilience and climate change adaptation.

1. Context

Actors organized in networks are considered to be motors of change. Research on networks highlights their essential role in the adoption and implementation of reforms (Rhodes, 2006) and the development of innovative practices (Powell and Grodal, 2005). The social sciences literature consistently demonstrates that actors' capacity to achieve their goals depends not just on their resources, but also on the number and quality of relationships they have with others (Kraatz, 1998; Provan et al., 2007; Uzzi, 1996). Networks of actors working together are seen to be especially useful in dealing with complex multi-level problems, such as those related to the environment (Betsill and Bulkeley, 2006; Davis and Stazyk, 2015; Waddell, 2016) and adaptation to climate change (Cloutier et al., 2014).

Studies highlight a number of potentially measurable features associated with network effectiveness. The heterogeneity of actors in a network reflects the sharing of information and resources, access to specialized resources and inter-organizational learning (Powell and Grodal, 2005). The structure of a network is based on the strength of links between actors (Granovetter, 1973), the presence of bridges linking peripheral sub-networks to central actors, and of bridges to fill structural holes between subgroups (Burt, 1992). Bridging actors fulfill an important strategic function in networks, helping to build consensus and enabling the transfer of information and ideas (Howells, 2006). A particular type of bridging actors called *boundary organizations* (Guston, 2001) designed to transmit and translate scientific information between researchers, decision-makers and civil society, occupy a special role in the network structure (Cash et al., 2006; Vignola et al., 2013). Beliefs, according to some authors, serve as 'glue' between network actors (May et al., 2006), and research suggests that divergence in beliefs between actors may lead to network structures that encourage actors to avoid one another (Henry et al., 2011). Inter-organizational coordination within the network has an impact on the achievement of a common goal. This is particularly important for objectives, such as resilience or environment-related questions, that require the active participation of several organizations (Ingold and Balsiger, 2015; Valiquette-L'Heureux and Therrien, 2013; Therrien et al., 2015). Coordination can be measured by the extent to which actors share a common language, the history of their relationship, sharing a common goal, and the fairness of the distribution of power (Therrien, 2010).

Social network analysis (SNA) conducted within organizations (Cross et al., 2002), or between organizations (Provan et al., 2007), is a strategic tool that can be especially valuable for issues requiring a high level of knowledge sharing. In this method, actors in a network are

* Corresponding author
E-mail address: mctherrien@enap.ca (M.-C. Therrien).

https://doi.org/10.1016/j.envsci.2018.11.016
Received 19 June 2018; Received in revised form 16 October 2018; Accepted 22 November 2018
Available online 17 December 2018
1462-9011/ © 2018 Elsevier Ltd. All rights reserved.

identified as nodes, and they are related to each other through relations. This creates a database, from which a number of metrics characterizing the network can be computed, and a mapping of relationships can be generated (Hawe et al., 2004; Haythornthwaite, 1996; Scott, 2017). The objective of SNA is to describe the structure of the network in order to then address deficiencies such as the fragmentation of groups, the lack of information sharing between subgroups, or the lack of connectivity to actors on the outskirts (Cross et al., 2002). Network analyses have been conducted to better understand the strengths and weaknesses of networks dealing with the management of natural resources (Reed et al., 2009), water management planning (Lienert, et *al.*, (2013) and the governance of climate change adaptation (Vignola et al., 2013). SNA also has potential practical applications, though these are underused, in identifying new potential allies, identifying weaknesses in the network (such as structural holes) and guiding the behaviour of actors towards a desired objective (Provan et al., 2007). Our research seeks to exploit this potential by coupling SNA with a strategy to use the analysis to inform network governance.

For complex issues such as resilience and climate change adaptation, theory suggests fostering information flows (Newig et al., 2010) and governance models that emphasize flexibility and local actors (Jaja et al., 2017), as these have been found to stimulate new ideas that are essential when facing complex challenges. Lienert et al. (2013) further suggests putting the accent on the cohesion between actors working towards a common goal. While previous network analys have shown how actors communicate information and influence public policy on resilience and climate change (Betsill and Bulkeley, 2006; Bulkeley, 2000, Davis and Stazyk, 2015), the present study is a first to focus on actors involved in the *implementation* of resilience and adaptation.

We conducted a SNA of organizations working across the territory of the city of Montreal on adaptation to climate change and resilience in order to delineate the network, and to understand contributors to the quality of network relationships that may influence policy implementation, a novel approach in SNAs.. In the first part of the paper, we present the applied methodology, the results of the SNA and characterize ties between organizations involved in climate change adaptation and the development of resilienceTwo of these actors are partners in the present study. Ouranos is a climate change consortium responsible for linking climate scientists and decision-makers on questions related to climate change adaptation; the City of Montreal plays a vital role as a policy-making organization. A better understanding of the links between actors working on these issues could enable Ouranos and the City of Montreal, as well as other organizations, to adjust their activities to facilitate exchanges and ultimately render the network more effective in promoting the resilience and adaptation of Montreal communities.

In the second part, we underline policy implications arising from analysis of how organizations are working together (or not) in a collective effort. We explore the potential contribution of insights offered by SNA for strategic development, and relate results obtained from the SNA to the way policies are implemented in Montreal. There are three leading policies related to resilience and climate change in Montreal: the Canopy Plan (Direction des grands parcs et du verdissement, Ville de Montréal, 2012) that sets tree-planting objectives for the city, the Climate Change Adaptation Plan (Service de l'environnement, Ville de Montréal, 2017) and the Resilience Strategy (unpublished, 2017) developed following the participation of the City of Montreal in the 100 Resilient Cities initiative of the Rockefeller Foundation.

2. Social network analysis of efforts towards adaptation and resilience in Montreal

Social network analysis (SNA) is a method for studying relationships between a set of actors. The emphasis is on the interactions and not the actors themselves. To apply this method, the actors are assigned to nodes, and relationships are the lines between nodes. This produces a map of the network. In order to better understand factors that contribute to shaping the network and that might inform actions that could be taken to strengthen the network, we further sought to obtain information about the strength, type and quality of relationships. The first step involved identifying actors involved in this informal network. The second step (undertaken concurrently with Step 1 in our research) involved collecting information that would enable us to design a questionnaire to capture data indicative of relationship strength and quality in this particular network. The third step was to analyze the survey data using SNA and tailor-made programs, and the fourth was to relate findings to policies around adaptation and resilience in Montreal.

2.1. Methodology

Network members were identified using a snowballing approach: an initial set of actors involved in climate change adaptation and resilience development activities on the territory of Montreal, spanning different sectors (public, community-based, other NGO, private or university-based) and levels (local, municipal, provincial, national, international) were identified. They were asked to name all organizations with which they have a relationship in work related to Montreal's climate change adaptation and resilience development. The exercise was repeated with actors identified in this initial round, and so on, until we reached saturation. We categorized organizations according to sector and level.

The boundaries of a network are not always easily defined, especially when membership is not official or geographically confined (Newig et al., 2010). We established the network's limit to organizations working on concrete measures to increase adaptation and resilience in the Montreal area. While we will present results in the next section, it is valuable to mention here that, at this initial stage, we found a very blurry informal network, meaning that actors are not necessarily aware they are part of a network. This effect is amplified by the fact that the notions of climate change adaptation and resilience are relatively new, especially in the context of concrete actions taken at the scale of a city. The distinction between adaptation and mitigation is also unclear for most of the actors. As one of the interviewees stated, "It's new, adaptation to CC plans. The trigger in the borough was when [the city's plan] was introduced, […] we were asked to participate.", and another, "It's really in the last year or year and a half and with the Municipalities for Climate Innovation Program that we understand that CCs are bringing changes to our everyday life and that we will need to adapt; that mitigation will not be enough to minimize the changes to come".

2.1.1. Questionnaire design

Along with identifying organizations that were part of this network, these early stage interviews (n = 18) were used to design the SNA questionnaire. Interview transcripts were coded using *NVivo* software and enabled us to identify types of relationship (i.e. the purpose of the relationship) between these organizations, and aspects contributing to the strength and quality of inter-organizational relationships that could be assessed in the SNA survey. Different *types* of relationship were identified in the interviews, including (in alphabetical order): collaboration, funding, intermediary (providing a link between other organizations), information and knowledge sharing, resource sharing, representation at local level, and skills sharing. For the *strength* of relationships, interviews validated the four data points identified by Kolleck (2012) as contributing to the likelihood of relationships persisting over time: (i) the perceived strength of the relationship on a scale from 1 to 5, (ii) the multiplexity (number of different types of relationship with the organization), (iii) whether the relationship is formalized, used as needed, or infrequent, and (iv) the presence or absence of mechanisms to maintain the relationship if the primary contact person leaves. Interviews also allowed us to identify factors that contributed to the quality of relationships (what makes a good or a bad relationship), something that, surprisingly, has not been done, to our

knowledge, in previous SNA studies.. These included:

1 *Administratively simple relations*: reasonable funding criteria, few administrative constraints, low structural and staff movement, etc.
2 *Openness and ease of reaching the organization*: the right person is easily found and contacted. This is facilitated by a personal and informal relationship. The contact person has the time and liberty to share the desired information, etc.
3 *The relationship produces good results*: quality of the exchanged information or services, competence of the organization, added value the relationship brings to the organization, etc.
4 *Respect for each actor's range of activity*: the organization does not infringe upon the mission or action area of its partner, there is general respect, etc.
5 Absence of competition.
6 *Right level of recognition*: the work accomplished collaboratively is recognized and acknowledged; there is respect for the informal hierarchy between organizations, etc.
7 *Long history of relationship*: longstanding relationship, frequent contact, contact with many people in the organization, etc.
8 *Shared objectives*: clear common goals on a given project.
9 *Similar values*: similar ways of working, same general goals, etc.
10 *Enjoyable relations*: at a person-to-person level.

Note that these 10 features, mentioned during interviews were associated with quality relationships by actors in this particular network, and may not apply to other networks. The importance of each feature varies even within our network according to the sector and level of an organization. In the SNA questionnaire, respondents were asked to evaluate the validity of affirmations (1), (2), (3), (5), (7), (8) and (9) on a scale from 1 = highly disagree to 5 = highly agree.

The questionnaire was distributed using Survey Monkey to the 170 actors identified in the interviews, of which 134 responded. Compiling data from the questionnaires, we built a database of relationships. We also asked respondents about non-relations (to capture deliberate decisions not to form relationships with another actor, and the reasons behind these decisions).

Survey data was analyzed using the SNA software *Gephi*, an open source software for SNA metrics and visualisation[1]. Homemade codes written in the *python* language were used to compute global averages, averages of targeted data (crossed-analysis), and relationships between different variables to identify co-varying variables. *Type* of relations is non quantitative. For analysis of *strength of relationships,* we used a quantitative estimate of strength achieved by combining the four data points. In analyzing *quality*, we omitted affirmations (4), (6) and (10) from the questionnaire because the information risked being more sensitive. From the seven retained measurements, we were able to evaluate the quality of the relationship. However, we avoided combining scores on different features of quality, which would pose problems regarding the weight of each feature. Instead, we analyzed each feature separately, and also add a measurement reflecting the degree of dependency between organizations by asking to rate on a scale from 1 to 5 the affirmation "I am dependent on this organisation for certain aspects of my activities".

Fig. 1 illustrates the method used to gather information on type, strength and quality of relationships between organizations in the network. The survey questions were designed based on early interviews. *Type* required respondents to select from a list of options, *strength* is quantitatively computed as expressed by the numbers, and *quality* involved Likert-type evaluation of the different aspects listed.

2.2. Main results

2.2.1. Network mapping

Fig. 2 shows the complete map of the network. The size of each node represents its *degree*, which is the number of relationships the organization has with other organizations. The colours represent *sub-groups* identified by the software,which identifies groups of actors that are more related to each other than to other actors. However, our map shows no clearly distinguishable sub-groups and it seems more apt to refer to organizations as located in two *poles*. The pole on the right groups mainly actors focused on local action (community organizations, small environmental groups), and the left pole groups actors focused on policy design (provincial and national organizations, companies). We are faced with a uniform network of weakly linked actors. The density, referring to the number of relationships divided by the total possible number of relationships, is just 0.094. The most important actors (with degrees larger than 20) are much more densely related, with a density of 0.44.

The orange nodes on the figure are what we could call brokers, which are not part of a specific pole, but rather create links between them. The two main organizations occupying this position are Ouranos and the City of Montreal. The City of Montreal has a complex internal structure. It has central and borough-level administrations, which are governed by their own mayors. Also, some cities on the Island of Montreal are not part of the City of Montreal, but have an important relationship with it. We call these connected cities. Therefore, the City of Montreal was split into two nodes: Centre City or *Ville Centre*, and boroughs and connected cities, which were grouped together under *Arrondissements*).

Ouranos and the City of Montreal (centre-city and boroughs) are also among the organizations with the most central roles in the network, along with the association of eco-centres called the REQ[2] and the Environmental Regional Council of Montreal (a politically active environmental NGO)[3]. These are identified as boundary organizations as they combine a high degree (number of relations), high betweeness centrality (number of times they link otherwise unrelated organizations) and a high closeness centrality (mean distance to all other organizations).

Network links between organizations from different sectors and levels

There are numerous relations between organizations from different sectors and levels. In Fig. 3, organizations are grouped according to sector, and we see a large number of lines linking each sector to the others. The highest concentration of relationships is in the triangle made up by public organizations, community-based organizations and other NGOs (about 40% of observed relations, see Fig. 3). The strength of relationships within and between sectors is presented in Table 1. The strength is high within and between community-based and other NGOs, and low with public sector organizations (see dark blue in Table 1). Table 2 presents results regarding the strength of relationships between organizations at different levels, and shows the strongest relationships between higher-level (provincial or national) organizations.

Associations between quality, strength and type of relationship

Analysis revealed interesting correlations between quality

[1] This software was used to construct the maps using the Force Atlas layout algorithm, to calculate the different metrics namely density, centralisation, individual centralities (based on Freeman 1979). The algorithm also identifies sub-groups as clusters of nodes with more relations to each other than to the rest of the network.

[2] In Montreal, every borough has an organization called the "Éco-quartier" (neighborhood eco-centre) mandated by the city to assume certain environmental responsibilities (informing citizens, distributing compost and recycling bins, etc.). These act as local environmental NGOs. The REQ is the assembly of all Éco-quartiers.

[3] The *Conseil Régional de l'Environnement de Montréal* (Montreal Regional Environmental Council) is an independent NGO that takes positions in various environmental debates.

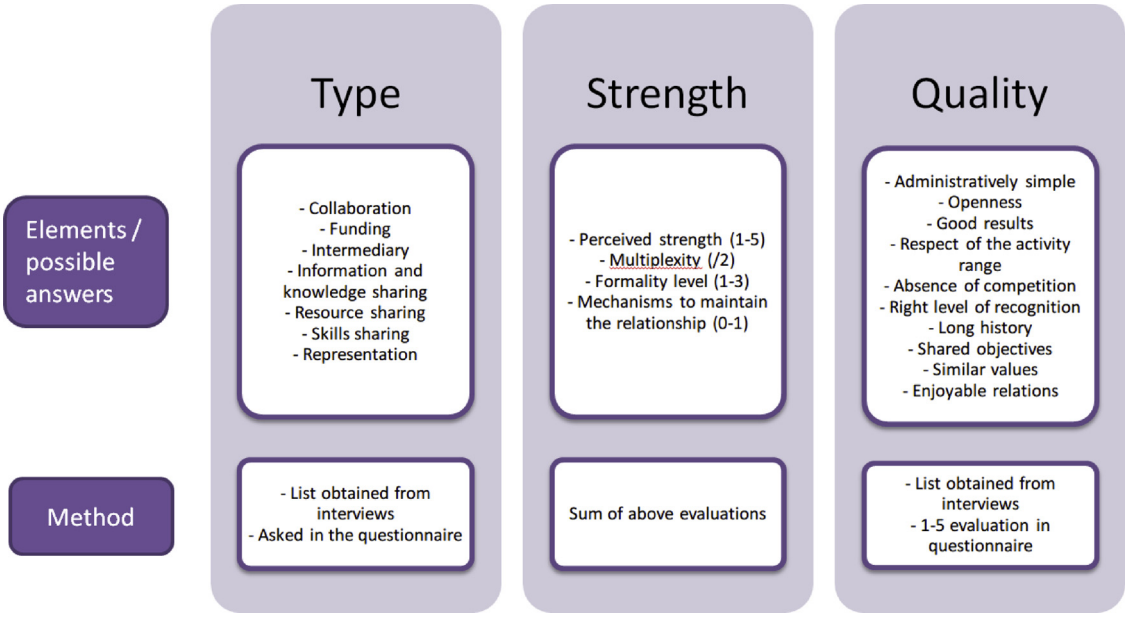

Fig. 1. Schematics of the different aspects of relationships evaluated in this study. We detail the possibles values or elements of each, as well as the mean of calculation or obtention.

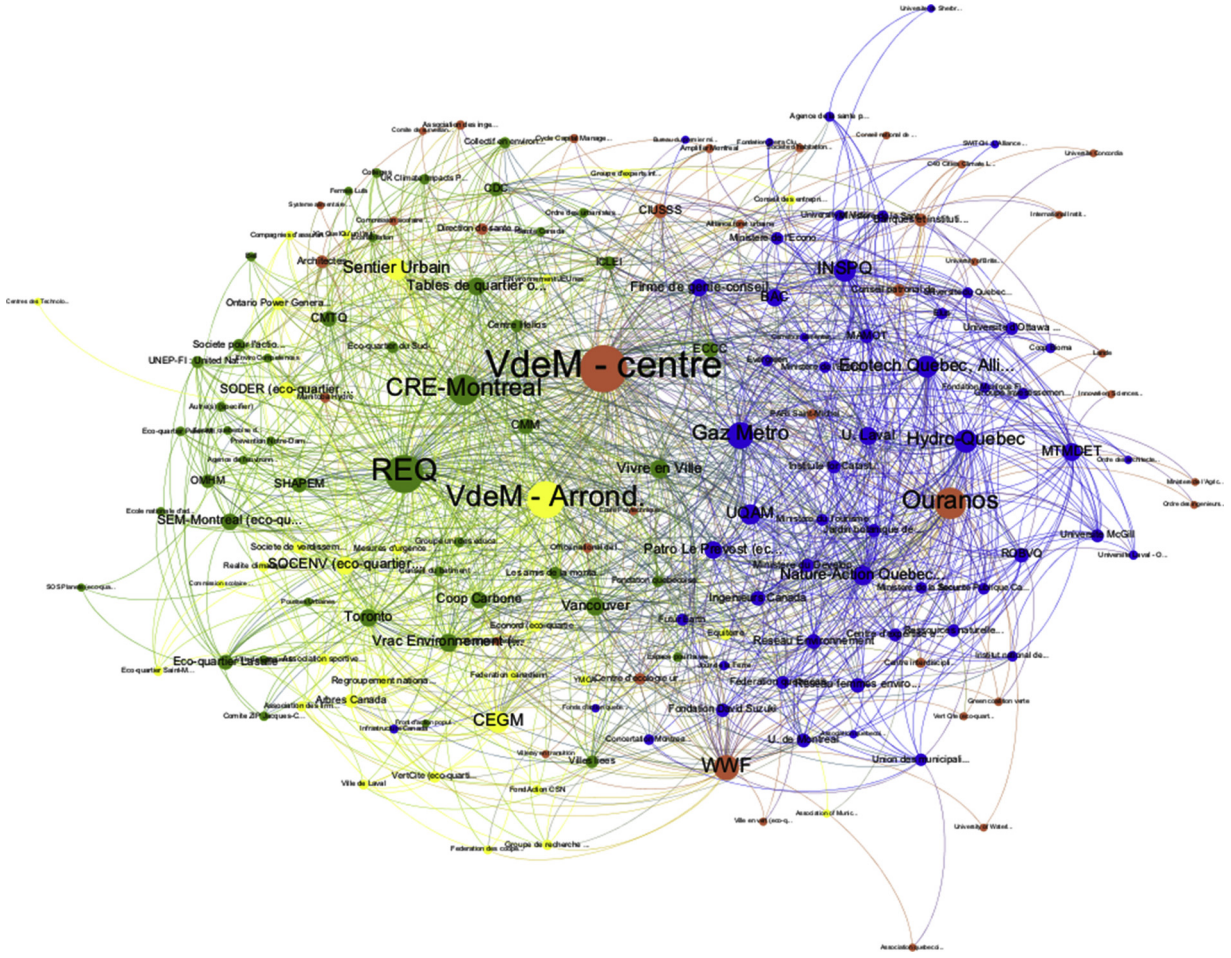

Fig. 2. Network map.
The size of the nodes represents their degree, or the number of relations an organization has. The color is given by what the software identifies as “sub-groups”, or groups of organizations that are more related amongst each other than to the rest of the network.

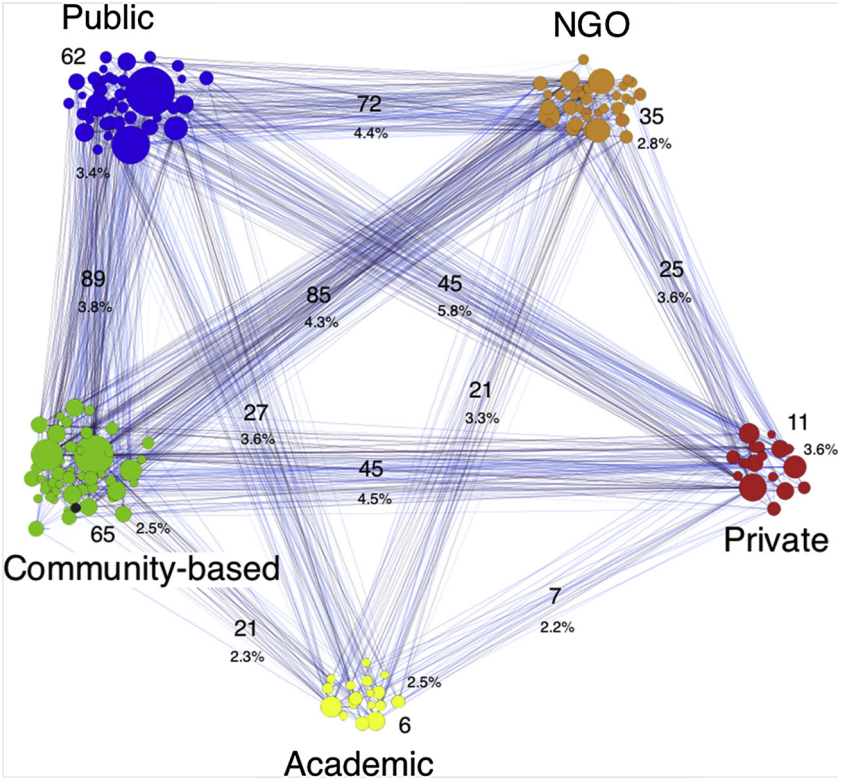

Fig. 3. Relationships between sectors.
The number of links between sectors is indicated, along with the percentage this represents compared to all possible links between those two sectors, which offers a better indication than the raw numbers of these relationships.

Table 1
Strength of relationships (likelihood of persisting over time) between organizations from different sectors.

Community-based NGO	3.03				
Other NGO	**3.22**	2.86			
Public	2.74	2.39	2.51		
Private	**3.19**	3.14	2.86	2.5	
Academic	3	3.07	**3.22**	**3.2**	**3.8**
	Community-based NGO	Other NGO	Public	Private	Academic

Table 2
Average strength of relationships between organizations of different levels

Local	2.83				
Municipal	2.59	2.66			
Provincial	3.09	2.65	3.03		
National	**3.25**	2.59	**3.11**	**3.4**	
International	2.67	2.47	**3.15**	**3.11**	*
	Local	Municipal	Provincial	National	International

* Insufficient data.

dimensions and strength and type of relationship in the network. For example, collaborative relationships were associated with weak links, but strong common goals. Sharing of information, skills and resources was associated with both strong relationships and common goals. (Specific insights from the quality analysis with relevance to policy are explored in the Discussion section). Further analysis explored correlations between quality and strength in relationships between organizations from different sectors and levels, using average scores of organizations at a given level/sector on different aspects of quality.

Looking at relationships between sectors, we found that relationships with the public sector were of lower quality than with other sectors (results not shown) and were characterized by a high degree of dependency.

Table 3
Average administrative ease of relationships (an aspect participating to relationship's quality) between different levels

Local	3.4				
Municipal	3.87	3.73			
Provincial	3.68	3.42	3.91		
National	**4.13**	3.59	**4.14**	**5**	
International	3.33	3.9	3.48	3.33	**4**
	Local	Municipal	Provincial	National	International

Between different levels, we found that, in relationships between higher-level organizations (provincial or national), there is greater ease in reaching contacts and greater administrative simplicity (Table 3); these relationships are also strong (see Table 2). However, organizations at higher levels have fewer shared objectives and values (Table 4) than seen among organizations at lower levels, which have weaker relationships (see Table 2). Goal commonality is especially strong in the small number of relationships with private sector organizations (results not shown, but similar to Table 4), and can be seen as the reason for forming links in the first place. In intermediary relationships, common

Table 4
Average measure of common values (an aspect participating to relationship's quality) between organizations at different levels

Local	4.2				
Municipal	**4.05**	**4.11**			
Provincial	**4.09**	3.5	**4.15**		
National	3.93	3.78	3.88	*	
International	3.83	**4.54**	**4.35**	*	*
	Local	Municipal	Provincial	National	International

* Insufficient data.

Table 5
Average evaluation of common values (an aspect participating to relationship's quality) between and inside subgroups

Green and yellow	4.01		
Blue	3.75	4.12	
Orange	3.72	**4.36**	**4.25**
	Green and yellow (local environmental)	Blue (policies)	Orange (rest and brokers)

goals appear less important.

3. Discussion

The literature on networks finds that information flows are stronger between densely knit actors (Haythornwhaite, 1996), but so is homophily (the tendency for a group to develop uniform ideas and means of addressing problems, reducing the potential for innovation essential for adaptive capacities); a tendency towards homogenization of information has also been noted, which further limits innovation (Bodin and Crona, 2009). In the network of organizations working on climate change adaptation and the development of resilience on the territory of Montreal, we see an absence of peripheral sub-groups, and efforts to strengthen ties between weakly linked peripheral organizations may be a means of accelerating innovation (Oubenal et al., 2017). The greater density of links among central organizations suggests capacity for co-management and collective action (Sandström and Rova, 2010; Bodin and Crona 2009), which are efficient forms of governance for sustainability related questions.

The SNA identifies a number of important boundary organizations, including our two study partners: Ouranos and the City of Montreal. Boundary organizations play an important role in information dissemination (Prell et al., 2009), have easy access to information and power, and act as mediators or gatekeepers (Lienert et al., 2013). We also found a large number of links between different sectors and levels. According to Ingold and Balsiger (2015) and Luthe et al. (2012), such a network form is beneficial for addressing sustainability questions. Scale crossing brokers are also essential for adaptive governance (Ernston et al., 2010).

The analysis correlating quality with type and strength of relationship provides important insights. We find that the quality of relationships is not the only, nor even the most important contributor to network links. Strong links with the public sector were accompanied by low quality and high dependency. Relationships with the private sector revealed especially strong goal commonality. Common goals and dependency therefore appear to encourage the maintenance of relationships, independent of their quality. The greater formality of higher-level relations makes them easier to maintain. Among organizations at lower levels, relationships are maintained not by ease of contact or strength of the relationship, but rather by the pursuit of common goals. In fact, common goals are an important basis for relationships between all sectors at all levels, with the exception of public organizations, which maintain formal prescribed relationships. This creates an important difference between what fosters quality and strong relationships among organizations in the left and right poles of the network (see Fig. 1 above); this finding needs to be considered in governance and policy, especially in the management of cross-scale relationships.

The finding that weak relationships can be maintained so long as there are common goals suggests that working towards common objectives is the main driver of relationships in this network. This is especially interesting given that many respondents reported feeling that the network lacks a clear objective that all actors can relate to and work towards together. As expressed by one actor in the early-stage interviews, "It seems that adaptation is 'in', so everybody wants to position themselves, and adaptation has links with many many subjects, many themes. […] We are all moving, but it is not structured. […] We are all in a large bubble right now, trying to position ourselves." A central objective might be expressed in policy, but it does not appear to translate into concrete instruments or clear communities of participation.

Related to common goals are common values. Whereas homophily tends to reduce the innovative capacity of networks by reducing the range of ideas, sharing common values and ways of thinking can be very helpful in maintaining quality relationships (Newman and Dale, 2005). In the present network, we find similar values between organizations at a same level, and between local-municipal and municipal-provincial organizations (see Table 4 above). There would appear to be a hierarchy in the network that facilitates relationships that respect this hierarchy. On the other hand, common value scores are low between "action-oriented" organizations in the left (yellow and green) pole and "policy-oriented" organizations in the right pole of Fig. 2. Common values are stronger factors in relationships between policy-oriented organizations and the brokers that appear in orange on the figure, as seen in Table 5. Organizations may develop similar values through direct contact with their brokers. Still, the relative weakness of common values between the blue and green/yellow poles reduces the chances that policies developed in the policy-oriented pole will be implemented in the action-oriented pole.

3.0.1. Existing and desired network structure

The social network analysis conducted in this project provides a first view of a network of organizations working to increase resilience and adaptation in Montreal. The network shape reveals high dependency on central actors who, at this point, appear poised to play an important role in the future evolution of network structure. Fig. 4 summarizes the network's characteristics in relation to what is known from the literature about how these characteristics impact on network dynamics and objectives.

Network structure involves a number of tradeoffs. A high degree of centralisation facilitates the coordination of actors and resources, but can also impede learning as it reduces access to multiple varied sources of information (Bodin et al., 2006). Collective action requires that the "wheels of decision-making" be oiled by information flows (Adger, 2003, p.389) between sectors and across scales, notably to capture local knowledge and capacity for action. In socio-ecological systems research, "It is argued that lay observations and knowledge about ecological change initiate transformations in the institutions related to the management of resources, which in turn modify the ways resources are used and thereby the landscape itself" (Gadgil et al., 2003, in Coté and Nightingale, 2012, p. 3). The present network displays a reasonably high centralization around the City of Montreal.

Cliques among less central actors serve to assemble and develop particular areas of expertise and knowledge and provide strength of voice and a degree of independence from central actors. Within cliques, high density has been found to strengthen trust and collaboration (Haythornwhaite, 1996). In the Montreal network, there would appear to be an opportunity for central actors and brokers, who now mediate links between these groups, to encourage the development of more independent and cohesive cliques around issue domains (greening, health, infrastructure, crises). We find a strong concentration and quality of relationships between community organizations and NGOs that could be exploited in encouraging this movement. Greater modularity could increase the visibility of sources of knowledge and expertise. This could help weave together the complex elements related to resilience and adaptation, but also increase public administration's

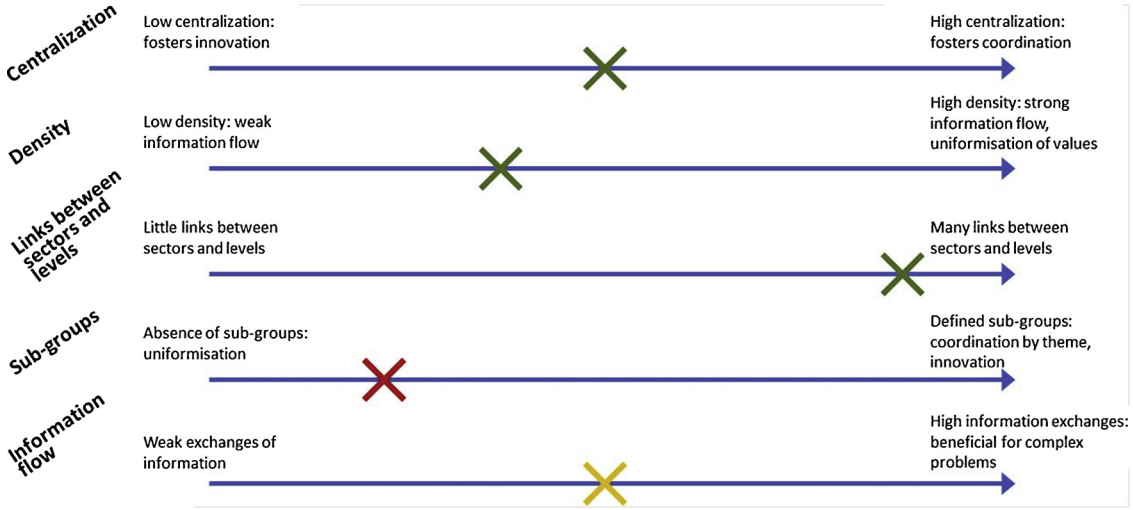
Centralization
Low centralization: fosters innovation
High centralization: fosters coordination
Density
Low density: weak information flow
High density: strong information flow, uniformisation of values
Links between sectors and levels
Little links between sectors and levels
Many links between sectors and levels
Sub-groups
Absence of sub-groups: uniformisation
Defined sub-groups: coordination by theme, innovation
Information flow
Weak exchanges of information
High information exchanges: beneficial for complex problems

Fig. 4. Network's characteristics.
Each line represents a network characteristic. The 'x' on the line represents the position of the present network from low to high on each characteristic. The color of the 'x' denotes whether this position is, according to the literature, good (green), so-so (yellow) or bad (red) for a network working for resilience and adaptation.

capacity as an institutional leader in this domain, not only from an informational perspective, but also from a relational perspective (Feldman and Khademian, 2007).

4. Implications for policy dialogue

In this next section, we discuss implications of the characteristics observed in the network for the goal of increasing urban resilience and climate change adaptation in Montreal. This discussion focuses on specific considerations for central organizations, as well as general considerations regarding network structure.

4.1. Role and impact of central organizations

In section 2.2.1, we saw that the City of Montreal, the REQ, the Environmental Regional Council of Montreal and Ouranos were identified as the most important organizations in the network. These organizations can be qualified as boundary organizations, also called brokers, and play a central role in coordinating the transmission of information across a network. This is an essential function in complex challenges such as adaptation to climate change (Bodin and Crona, 2009; Haythornwhaite, 1996; Vignola et al., 2013). These brokers know the network well enough to connect organizations that would benefit from being connected (Bodin et al., 2006). These are organizations that "spend time and resources engaging with both local managers and regional planners and create pathways to higher levels whilst retaining their relationships to communities and their abilities for localized learning and action." (Mills et al., 2014, p.9) An important network function involves facilitating connections between those responsible for planning (whether at national, provincial or municipal level) and those responsible for local action (Mills et al., 2014, p. 6). In Montreal, borough offices, the CRE and REQ appear as actors well-placed to assume this role at municipal level, though it was beyond the scope of this study to not explore the upward transmission of information related to local action. Moreover, the CRE and REQ are the organizations with the most independence, being able to obtain information directly. The City of Montreal holds the most important position as a bridging organization that links otherwise isolated groups.

A modular network would see these bridging organizations provide a link from densely connected cliques to other network members in a structure that helps to maintain heterogeneity in a well-connected network. The position held by these organizations allows them to learn about different groups and how to connect them to work towards collaborative solutions, knowledge that could be put to use in fostering links among these organizations. In Montreal, bridging organizations tend, rather, to relate to other organizations on an individual basis, leading to concerns around control and excessive influence.

The City of Montreal, from which policies emanate, is the central organization around which the network is organized. As is typical of public administration, it is highly compartmentalized, and this has a potential impact on internal network relationships and information flows. In the present study, the City of Montreal appears as a single organization, with information entering from organizations on one side and being transmitted to organizations on the other side. However, the actual workings within the City of Montreal may not be so direct. As a central actor in the urban network, it would be beneficial to conduct a separate social network analysis internally of the City of Montreal with the aim of creating a knowledge map (Eppler 2001, in Chan 2005) to facilitate the process of locating relevant expertise (by both internal and external actors), identifying areas of duplication or synergy, and generally elucidating this hub from which other network links emerge. It would also help to understand how these internal relationships create capacity to enable (or hinder) communities of participation (Feldman and Khademian, 2007). Such an analysis might further seek to identify the external connections nurtured by each department.

Ouranos is a non-profit organization that strives to act as a broker between scientific developments on climate change and policies developed at the governmental level. However, the SNA shows the organization to have only a medium betweenness centrality score (indicating how often an organization links otherwise unconnected organization). This lower than expected strength as a broker appears related to the few connections Ouranos has with the local action-oriented organizations on the left of Fig. 2. It also appears related to the weak representation of, and weakness of relationships among, academic organizations, for which Ouranos would hope to act as a broker and link them to the rest of the network. Its position among the policy-oriented grouping of organizations is congruent with its mandate, but may limit its strategic influence on the broader network and be indicative of a lack of cohesiveness around network goals. That said, organizations connected to Ouranos report very high satisfaction with the relationship ("Right now, I cannot imagine what the Province of Quebec would be without Ouranos for adaptation to CC", as one interviewee stated), indicating that the organization's own choices of relationships are likely key to expanding its strength as a network broker.

One of the characteristics of a boundary organization is that it links sub-groups that are otherwise unconnected to the rest of the network,

filling what are called “structural holes”. An organization willing to explicitly take up this role may act as an intermediary between, for example, planning and action in terms of adaptation to climate change. The present network does not have such structural holes, as it is not organized into sub-groups. Organizations willing to augment their brokering role, such as Ouranos, would need to take action to accelerate the generation of such subgroups, and then fill structural holes.

4.2. Structural implications

In this network, the concept of resilience encompasses a wide range of preparedness, risk mitigation, crisis response and recovery activities pursued by distinct sets of organizations. They are linked through recognition that each also contributes to a broader goal of urban resilience. In interviews at the early stage of the SNA, most organizations identified with a particular concern, with only a few seeing their role in a manner coherent with resilience. The network therefore serves not only to strengthen relationships between organizations working toward a common goal but also to spread and sustain recognition of resilience as that common goal. This makes it different from networks focused on more specific (and potentially measurable) goals (i.e. water management). This finding was made possible by our addition of quality analysis to the SNA, and constitutes a key innovative contribution of this research. Quality analysis revealed a large discrepancy in what contributed to quality relationships for organizations from different sectors and at different levels of this network; in particular, it highlighted that common goals were essential to relationships between higher level and lower level organizations.

As mentioned earlier, the network displays a uniform structure of weak density. We believe the form of this network reflects the relative novelty of adaptation and resilience projects in Montreal. In the early-stage interviews, many actors complained about the difficulty of knowing who does what in the network, and who to contact for a given purpose. For example, one respondent explained: “The challenge is specifically this coordination, which is to say we do not want to duplicate the work of others.” The network has not yet reached a high state of coordination and efficiency, which may explain the uniformity of the network (with no apparent sub-groups) and its weak density. The governance, formal or not, of such a network, appears quite different from governance organized around thematic sub-groups of similar organizations. While in the latter case, governance is distributed among brokers relating these sub-groups, in the present network, central organizations carry the weight of the network in an unspecialized manner, which has an impact on policy design and efficient practices. Given that peripheral organizations are the source of innovation, with enough distance to avoid a homogenization of ideas, a centered-governance lacking brokers will have difficulty engaging those actors and flowing information to and from these edges of the network.

Policies appear to have considerable influence on network structure (Keast et al., 2004). In Montreal, current policies are organized around three priorities: the Canopy Action Plan, which provides funding to increase green cover in the city, the Climate Change Adaptation Plan of the City of Montreal and the Urban Resilience Strategy. We could also include adaptation plans from other public organizations at provincial and national levels. The Canopy Action Plan promotes local initiatives and the activities of implementation organizations. The other plans seem to have little concrete impact, despite the numerous relationships they officially generate. Perhaps those policies would benefit from encouraging the development of more “bridging” links, relating organizations to resources available in the network. Bridging links show ties of loosely coupled organizations that span groups which have different and diverse characteristics (Aldrich and Meyer, 2014). At present, adaptation plans are characterized by strong, formal and administratively regulated relationships, characteristic of “bonding” links. Bonding links in social capital are characterized by homophily, meaning high levels of similarity in the characteristics of the organizations such as…. (Aldrich and Meyer, 2014).

Our SNA shows a more developed network around activities that fall under the scope of the Canopy Plan, as seen in the expansive and organized pole on the right of the network map (Fig. 2), focused on greening and local action. This well-developed part of the network would point to significant impact of the Canopy Plan of the City of Montreal at greening the city by funding and facilitating the work of local organizations. Its success may be attributed to the emphasis on local action in this plan. While this policy seems to have brought more concrete results than the City’s adaptation plan, Scott (2015) warns us that SNAs tend to put projects that direct governance towards the local level in a better light, while discounting the importance of institutions and their interrelations. The two other plans are represented mainly in the blue pole of the network, composed of actors at a higher decision-making level involved more in the development of plans and policies for adaptation to climate change and resiliency building than in concrete actions. From the SNA, the Climate Change Adaptation Plan of the City of Montreal and the Urban Resilience Strategy do not show any clear structure in the network, even if some relationships are explicitly expected in these plans. The addition of quality evaluation to this SNA allows us to understand where this difficulty could be coming from. The variable level of understanding between different sectors and levels observed (Tables 3 to 5) shows the lack of definition around goals of these adaptation plans. Moreover, the final purpose of those strategies is to have a tangible impact in the field. This is possible through connections between the left and the right poles. Given the different definitions of quality relationships and values observed (see section 2.2.2), brokers are of key importance in the success of cross-pole relationships. In terms of implementation, the absence of a network to support those two plans helps explain their low impact.

4.3. Building network social capital as a potential development strategy

The breadth of resilience and adaptation work complicates efforts to assess and track network effectiveness at achieving progress. However, networks can be seen as having an intrinsic value in resilience and climate change adaptation. Resilience involves collective action resulting from networks of interactions and information flows between individuals or organizations. These networks are social capital, which is central to “the lived experience of coping with risk” (Adger, 2003, p.389). Networks developed for one purpose are then positioned to collaborate on other challenges that arise, as seen in networks developed for sustainable co-management of ocean resources that also work on disaster planning. In this sense, “the existence of the networks themselves promotes adaptive capacity” (Ibid, p. 398). Networks can operate in synergy or in opposition to the state. Adger describes the idealized situation as a well-functioning state with high levels of networking social capital, where there is a synergy between the state and civil society that promotes social and policy learning (Ibid, p. 394) and a shared vision of risk and adaptation. Social networks can also compensate for weakness in a state’s ability to mitigate risk or recover from disasters.

Network development can thus be seen as a good in and of itself. From this perspective, the present exercise may be seen less as an evaluation of network effectiveness than as a step towards strategic network development. In terms of policy implications, some authors suggest that investments should be directed towards projects where there is already a strong and well connected network (Mills et al., 2014). However, others stress that while networks can be helpful to adaptation when they are composed of the ideal mix of “bridging” links and “bonding” links, they are not beneficial when characterized by too many “bonding” links (Bodin et al., 2006 ; Newman and Dale, 2005). “Bridging” links relate organizations to resources available in the network. “Bonding” links “*impose constraining social norms and foster group homophily*” (Newman and Dale, 2005). In the present study, the quality of relationships may serve to differentiate between “bridging” and

"bonding" links.

5. Conclusion

This Social Network Analysis (SNA) of organizational actors working for adaptation to climate change and resilience building in Montreal revealed a uniform, weakly linked network, composed of two poles and centralized around the City of Montreal. We see that the current centralization around the City of Montreal may be beneficial for coordination, but that evolving the current uniform structure to encourage more sub-networks connected to this central organization could improve prospects for innovation. One pole, associated with local action, relates to a greening policy developed by the city. However, the city's two other main policies are not well represented in the network. Moreover, there appears to be an important difference between what fosters quality relations in each of the two poles, reducing the chances that the policies developed in the policy-oriented pole will be implemented in the action-oriented pole. The method we apply, which incorporates quality assessment into a SNA, delivers insights into how to act on a network to improve relationships and achieve a network structure suited to the goals of adaptation and resilience.

6. Further research

This research aimed to support practical efforts in the City of Montreal to strengthen the informal network of organizations working towards climate change adaptation and resilience. Findings point to a number of governance strategies that might be adopted by central organizations to promote sub-group formation and to the importance of clarifying common goals that serve as important glue between organizations. The research also introduces the notion of quality into social network analysis, finding that distinct quality dimensions exert an important influence on the formation of network links between different sectors and levels of organization. As a methodological innovation, the incorporation of quality opens interesting new possibilities for SNA that could be explored in different domains. Further research is needed on the translation of SNA results into network development strategies that incorporate consideration for the quality of relationships.

References

Adger, W.N., 2003. Social Capital, Collective Action, and Adaptation to Climate Change. Economic Geography 79 (4), 387–404.

Betsill, M.M., Bulkeley, H., 2006. Cities and the multilevel governance of global climate change. Global Governance: A Review of Multilateralism and International Organizations 12 (2), 141–159.

Bodin, O., Crona, B., Ernston, H., 2006. Social Networks in Natural Resource Management: What Is There to Learn from a Structural Perspective? Ecology and Society 11 (2) r2.

Bodin, O., Crona, B.I., 2009. The role of social networks in natural resource governance: What relational patterns make a difference? Global Environmental Change 19, 366–374.

Burt, R.L., 1992. Structural Holes. Harvard University Press, Cambridge, MA.

Bulkeley, H., 2000. Discourse coalitions and the Australian climate change policy network. Environment and Planning: Government and Policy 18 (6), 727–748.

Cash, D.W., Adger, W.N., Berkes, F., Garden, P., Lebel, L., Olsson, P., et al., 2006. Scale and cross-scale dynamics: governance and information in a multilevel world. Ecology and society 11 (2), 8.

Cloutier, G., Joerin, F., Dubois, C., Labarthe, M., Legay, C., Viens, D., 2014. Planning adaptation based on local actors' knowledge and participation: a climate governance experiment. Climate Policy 1–17.

Coté, M., Nightingale, A.J., 2012. Resilience Thinking Meets Social Theory: Situating Social Change in Socio-Ecological Systems (SES) Research. Progress in Human Geography 36 (4), 475–489.

Cross, R., Borgatti, S.P., Parker, A., 2002. Making invisible work visible: Using social network analysis to support strategic collaboration. California management review 44 (2), 25–46.

Davis, R.S., Stazyk, E.C., 2015. Examining the Links between Senior Managers' Engagement in Networked Environments and Goal and Role Ambiguity. Journal of Public Administration Research and Theory 26 (3), 433–447.

Direction des grands parcs et du verdissement, Ville de Montréal, 2012. Plan d'action canopée, 2012-2021. Retrieved from http://ville.montreal.qc.ca/pls/portal/docs/PAGE/COMMISSIONS_PERM_V2_FR/MEDIA/ DOCUMENTS/DOCCONSULT_PLANACTION_20120918.PDF.. .

Feldman, M.S., Khademian, A.M., 2007. The role of the public manager in inclusion: Creating communities of participation. Governance 20 (2), 305–324.

Granovetter, M.S., 1973. The strength of weak ties. American journal of sociology 1360–1380.

Guston, D.H., 2001. Boundary organizations in environmental policy and science: an introduction. Science, Technology, & Human Values 26 (4), 399–408.

Hawe, P., Webster, C., Shiell, A., 2004. A glossary of terms for navigating the field of social network analysis. Journal of Epidemiology & Community Health 58 (12), 971–975.

Haythornwhaite, C., 1996. Social network analysis: An approach and technique for the study of information exchange. Library & information science research 18 (4), 323–342.

Henry, A.D., Lubell, M., McCoy, M., 2011. Belief systems and social capital as drivers of policy network structure: The case of California regional planning. Journal of Public Administration Research and Theory 21 (3), 419–444.

Howells, J., 2006. Intermediation and the role of intermediaries in innovation. Research policy 35 (5), 715–728.

Jaja, J., Dawson, J., Gaudet, J., 2017. Using Social Network Analysis to examine the role that institutional integration plays in community-based adaptive capacity to climate change in Caribbean small island communities. Local Environment 22 (4), 424–442.

Keast, R., Mandell, M.P., Brown, K., Woolcock, G., 2004. Network structures: Working differently and changing expectations. Public administration review 64 (3), 363–371.

Kraatz, M.S., 1998. Learning by association? Interorganizational networks and adaptation to environmental change. Academy of management journal 41 (6), 621–643.

Kolleck, N., 2012. Supporting decision-making for sustainable development: Social Network Analyses and Social Network Theory as a tool for policy advice. Berlin Conference on Human Dimensions of Global Environmental Change.

Lienert, J., Schnetzer, F., Ingold, K., 2013. Stakeholder analysis combined with social network analysis provides fine-grained insights into water infrastructure planning processes. Journal of environmental management 125, 134–148.

Luthe, T., Wyss, R., Schuckert, M., 2012. Network governance and regional resilience to climate change: empirical evidence from mountain tourism communities in the Swiss Gotthard region. Regional Environmental Change 12, 839–854.

May, P.J., Sapotichne, J., Workman, S., 2006. Policy Coherence and Policy Domains. The Policy Studies Journal 34 (3), 381–403.

Mills, M., Álvarez-Romero, J.G., Vance-Borland, K., Cohen, P., Pressey, R.L., Guerrero, A.M., Ernstson, H., 2014. Linking Regional Planning and Local Action: Towards Using Social Network Analysis in Systematic Conservation Planning. Biological Conservation 169 (January), 6–13.

Newig, J., Günther, D., Pahl-Wostl, C., 2010. Synapses in the network: learning in governance networks in the context of environmental management. Ecology and Society 15 (4).

Powell, W.W., Grodal, S., 2005. Networks of innovators. The Oxford handbook of innovation 56–85.

Provan, K.G., Fish, A., Sydow, J., 2007. Interorganizational networks at the network level: A review of the empirical literature on whole networks. Journal of management 33 (3), 479–516.

Reed, M.S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Stringer, L.C., 2009. Who's in and why? A typology of stakeholder analysis methods for natural resource management. Journal of environmental management 90 (5), 1933–1949.

Rhodes, R.A., 2006. Policy network analysis. The Oxford handbook of public policy 423–445.

Scott, J., 2017. Social network analysis. Sage.

Service de l'environnement, Ville de Montréal, 2017. Plan d'adaptation aux changements climatiques de l'agglomération de Montréal 2015-2020 (ISBN 978-2-922388-76-3). Retrieved from. http://ville.montreal.qc.ca/portal/page?_pageid=7237,75085661&_dad=portal&_schema=portal.

Therrien, M.C., 2010. Stratégies de résilience et infrastructures essentielles. Telescope 16 (2), 154–171.

Therrien, M.C., Beauregard, S., Valiquette-L'Heureux, A., 2015. Iterative Factors Favoring Collaboration for Interorganizational Resilience: The Case of the Greater Montréal Transportation Infrastructure. International Journal of Disaster Risk Science 6 (1), 75–86.

Uzzi, B., 1996. The sources and consequences of embeddedness for the economic performance of organizations: The network effect. American sociological review 674–698.

Valiquette-L'Heureux, A., Therrien, M.C., 2013. Interorganizational dynamics and characteristics of critical infrastructure networks: the study of three critical infrastructures in the Greater Montreal Area. Journal of Contingencies and Crisis Management 21 (4), 211–224.

Vignola, R., McDaniels, T.L., Scholz, R.W., 2013. Governance structures for ecosystem-based adaptation: Using policy-network analysis to identify key organizations for bridging information across scales and policy areas. Environmental science & policy 31, 71–84.

Waddell, S., 2016. Societal Change Systems A Framework to Address Wicked Problems. The Journal of Applied Behavioral Science 52 (4), 422–449.

Marie-Christine Therrien Ph.D. Professor, École nationale d'administration publique and Director of Cité-ID LivingLab Urban Resilience Governance, Marie-Christine Therrien is a full professor of management at the **École nationale d'administration publique, and Director of the Cité-ID LivingLab in Urban Resilience Governance**. Her research focuses on resilience governance, complex organizations and crisis management, looking in particular at issues around network coor-dination, analysis of organizational failure, knowledge transfer, organizational resilience, and crisis management.

Mathilde Jutras, M.Sc., Research professional, École nationale d'administration publique Following studies in physics and climatology at the Université de Montréal and McGill University, Mathilde Jutras has worked, since spring 2017, as a research professional on a number research projects related to the Cité-ID LivingLab. Her focus is on assuring the development and completion of research projects on urban resilience. Among her complet-ed projects stands a mapping of the relationships between actors of adaptation to climate change and resilience development in Montréal.

Susan Usher, M.A, Doctoral candidate, École nationale d'administration publique Susan Usher, MA (Pol. Econ.), is a doctoral candidate at the École nationale d'administration publique, focusing on patient and citizen engagement as a lever of transformation in health systems. She is Director of the Health Innovation Forum, collaborating with the McGill University Health Centre to explore policy challenges arising in healthcare organizations. In 25 years as Director of the Health Policy Division and of Patient Publications at Parkhurst Publishing, she worked with healthcare providers, decision-makers and patients, producing events and reports to support capacity development and improvement in Canada's health systems.